Preliminary evaluation of volume-rendered three-dimensional display of time-of-flight MR angiography in the diagnosis of intracranial aneurysms

**Abstract** We assessed the value of the volume-rendering method of displaying images of three-dimensional (3D) time-of-flight MR angiography (MRA) in the diagnosis of intracranial aneurysms. We obtained three-dimensional volume-rendered MRA from 21 patients with intracranial aneurysms. The images were evaluated in comparison with maximum-intensity-projection images (in 21 patients), conventional angiograms (in 21) and CT angiography (in nine). In 17 patients, 3D volume-rendered images were thought to show morphological features most clearly. They were superior to the other methods for demonstrating the precise location of the aneurysm in three patients and in showing the shape of the bleb in another three. 3D volume-rendered MRA can be effectively added to conventional imaging techniques for diagnosis of intracranial aneurysms.

**Keywords** Magnetic resonance angiography · Intracranial aneurysms

**Introduction**

Maximum intensity projection (MIP) has been widely employed for postprocessing data acquired in three-dimensional (3D) time-of-flight (TOF) cerebral MR angiography (MRA). The volume-rendering technique is another method for displaying 3D angiographic images when optimal demonstration of surface characteristics or internal structure is required. Details of this technique have been discussed elsewhere [1, 2, 3]. Developments in computer hard- and software have made the volume-rendering technique practical in the clinical setting [3, 4, 5, 6]. Our objective was to assess the value of this technique in the diagnosis of intracranial aneurysms.

**Materials and methods**

After 3D TOF MRA was performed at 1.5 tesla, the data were transferred to a workstation for postprocessing using the volume-rendering technique. This method was applied to 21 consecutive patients (seven men, and 14 women, aged 44–74 years) with a suspected aneurysm on MIP of conventional MRA. They were later assessed as having 25 unruptured aneurysms. The diagnosis was established by conventional angiography in all patients and confirmed by CT angiography (CTA) in nine. In conventional digital subtraction angiography (DSA), in addition to anteroposterior and lateral views, several oblique views with magnification were obtained to clearly demonstrate the aneurysm(s). CTA was performed using single-slice helical scanning, 1 scanning cycle/s, table feed speed 1 mm/s, scanning time 60 s, slice thickness 1 mm, reconstruction interval 1 mm. We injected 100 ml nonionic iodinated contrast medium (300 mg/ml) at 2–2.5 ml/s into an antecubital vein using a power injector, starting 25–30 s before the initiation of scanning. After the completion of scanning, we reconstructed 9–15 3D CT angiograms above a threshold of 100–130 Hounsfield units, employing the volume rendering technique.

There were 24 saccular aneurysms 2–28 mm in diameter (mean 9.0 mm) and one 9-mm fusiform aneurysm of the middle cerebral artery. Of the 24 saccular aneurysms, 12 were on the internal carotid artery, six on the middle cerebral, three on the basilar, two on the anterior cerebral and one in the anterior communicating artery. 3D TOF MRA was performed using the following parameters: TR 39 TE 6.8 ms, field of view 17 cm, matrix 160 × 256, slab thickness 50–60 mm, section thickness 1 mm. Magnetisation transfer contrast and an inclined flip angle of 10–30 degrees (mean 20 degrees) were employed. In each patient, volume-rendered 3D-display im-
ages viewed from 6–15 angles were generated and recorded using the standard software incorporated in the workstation. In 19 patients, partially reconstructed images were also generated around the aneurysm by limiting the area to be reconstructed using a curved line on the console.

Two neuroradiologists blinded to the final diagnosis independently compared 3D-display images against MIP MRA (a superior-inferior view and 11 views created around the z axis, in 21 patients), conventional angiograms (21 patients), and CT angiography (nine patients). On each examination, the patients were classified visually as follows: group 1: patients in whom 3D-display images most clearly showed the aneurysm(s); group 2: patients in whom 3D-display images were judged equal to one or both other types; and group 3: patients in whom other images most clearly depicted the aneurysm(s). Particular attention was paid to the demonstration of the neck and dome and their relationships to the parent artery. In cases of disagreement, the final judgment was by consensus. Interobserver concordance was evaluated using the kappa test.

Results

About 30–45 min were required for data transfer and reconstruction of volume-rendered 3D-display images.

The initial interpretations of the two readers agreed as regards to the three subgroups in 18 patients (86%). The kappa score for interobserver reproducibility was 0.64 (substantial reproducibility). In 17 patients, 3D-display images were thought to show the morphological features of the aneurysms most clearly (Figs. 1, 2). In the other four patients, conventional angiograms were judged to provide the clearest demonstration in one with a 27-mm internal carotid artery aneurysm, while 3D-display images were comparable to MIP in three, who had a 9-mm middle cerebral, and 9 and 5-mm internal carotid artery aneurysms, respectively. The two readers found the volume-rendered 3D display was particularly superior to the other methods for demonstrating the precise location of the aneurysm in three patients and the shape of the bleb in another three. They also found that partial reconstruction around the aneurysm was useful for assessing its morphology in all 19 patients in whom this technique was applied.

Discussion

3D TOF is the MRA technique most frequently employed for diagnosis of intracranial arterial disorders, mainly because of its excellent spatial resolution, despite the limited extent of the imaging slab and the relatively long acquisition time. In the clinical situation, the data obtained are generally displayed after postprocessing by the MIP method. For some diseases, combined interpretation of the MIP and source images has been reported to improve diagnostic accuracy [7,8].

The volume-rendering and surface-rendering methods are used to generate 3D images from MRI or CT data-sets. The surface-rendering method uses only the data outlining the target object, while volume-rendering uses the data for all voxels obtained from the target object. Accordingly, data processing for the latter is more time-consuming. However, technical developments have made volume-rendering method clinically practical. Even when used to display the surfaces of an anatomical structure, as in MRA, volume-rendering retains the spatial resolution of the original data. Combining it with 3D TOF MRA, as in this study can be expected to provide good quality 3D-display MRA images.

We found volume-rendered 3D display of great value for assessment of intracranial aneurysms, as suggested by Maeder et al. [9]. In most cases, it was thought superior to the other imaging methods for characterising features such as the morphology of the neck and dome of the aneurysm and their relationship to the parent artery. Needless to say, this information is of great importance preoperatively. It should be noted that, even using our technique, MRA does not demonstrate flow into and out of the aneurysm, which on catheter angiography yields important information about the site and size of the neck and involvement of adjacent branches. On the contrary, complex flow within the aneurysm can limit assessment of its lumen and fine distal vessels. Partial reconstruction around the aneurysm, as performed in conventional MIP, was found useful in demonstrating the features of the aneurysm, because superimposition of vessels was reduced and the aneurysm could be viewed from any desired angle. While carrying out this study, we examined six other patients in whom an aneurysm was suspected on conventional MRI and/or MRA. Using 3D-display images, we excluded an aneurysm and decided to manage these patients with careful follow-up. Although these patients did not undergo catheter angiography, the information obtained by the volume-rendering technique would be expected to be useful in supporting that obtained by the MIP technique in showing the presence or absence of intracranial aneurysms.

Differences in the thresholds used in postprocessing can change the apparent size of the aneurysm, but we believe this may be at least partly overcome by referring to source images. Another limitation is that the spatial resolution of 3D-display MRA cannot exceed that of the original 3D TOF data. Our study is also limited because we did not compare our technique with 3D DSA, which is not available in our institution.